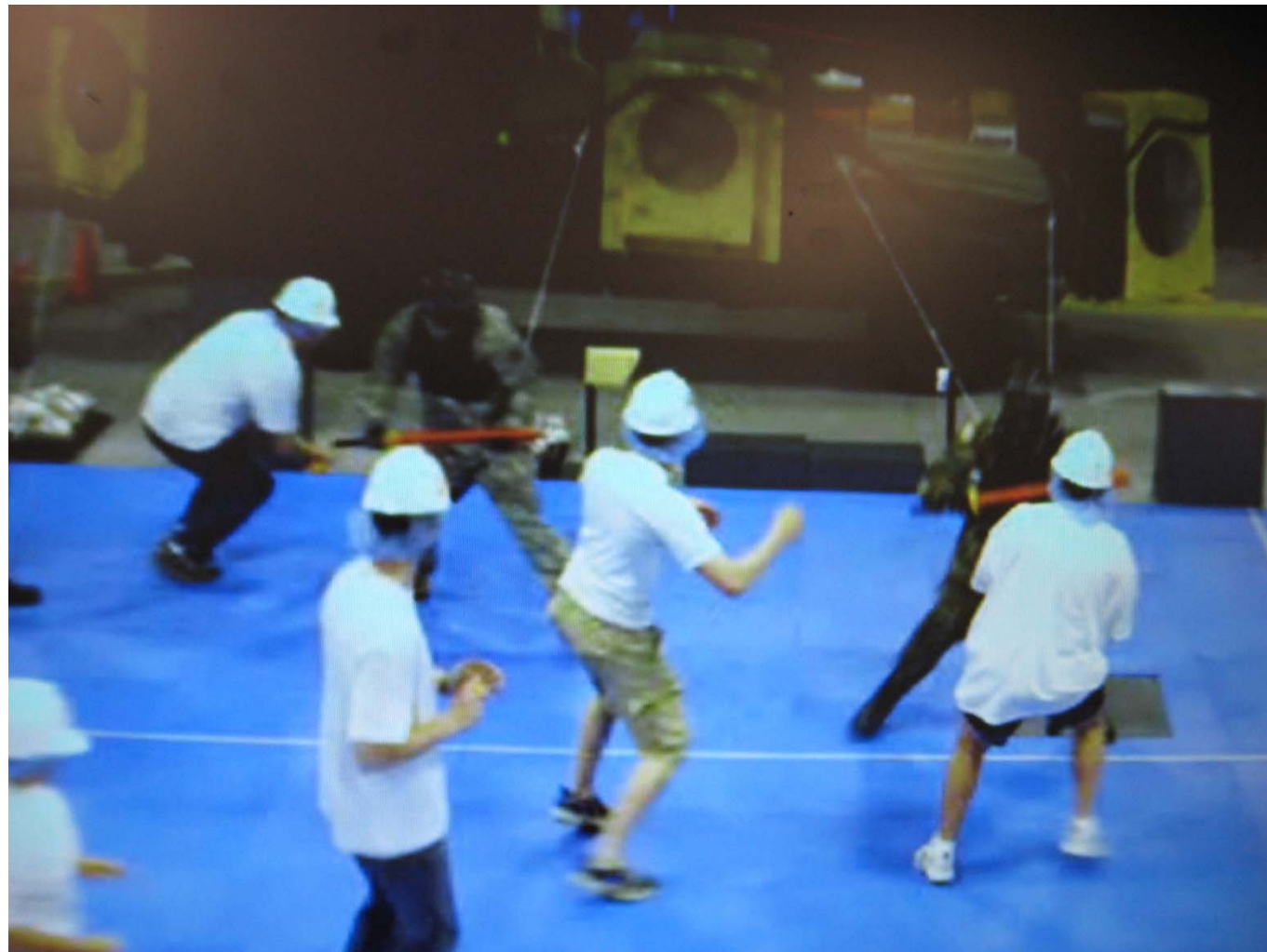




Laboratory Crowd Behavior



UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Report Documentation Page			Form Approved OMB No. 0704-0188		
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 25 JUN 2010		2. REPORT TYPE Conference Presentation		3. DATES COVERED 00-00-2008 to 00-00-2010	
4. TITLE AND SUBTITLE Laboratory Crowd Behavior Presented at the Force Effectiveness, Analysis, and Techniques Workshop, June 25, 2010. Weehawken, New Jersey.				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Elizabeth Mezzacappa; Gordon Cooke				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Army, ARDEC, Target Behavioral Response Laboratory, RDAR-EIQ-SD, Building 3518, Picatinny Arsenal, NJ, 07806-5000				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT Laboratory Crowd Behavior at the Army's Target Behavioral Response Laboratory.					
15. SUBJECT TERMS crowd, Lewin, field theory, non-lethal weapons, crowd metrics, crowd modeling and simulation, laboratory data, human behavior, social network analysis, effectiveness metrics, effectiveness testing, non-lethal weapons effectiveness, laboratory data, crowd research, empirical modeling					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Public Release	18. NUMBER OF PAGES 45	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

- Large numbers
- Heterogeneous
- Individual Actors
- Interdependence
- Language Barriers
- Empirical testing is difficult





Methods



Gather empirical
data on
real people and
real groups in
tactically relevant
situations



UNCLASSIFIED- Approved for Public Release

3

UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Conceptual Framework



- Based on the work of Kurt Lewin
- *Field Theory in Social Science* (1948)
- *Principles of Topological Psychology* (1936)



UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Indoor Crowd Behavior Testbed Layout

Video Cameras on Trusses





- Groups of 12-19 individuals
- Controlled motivations toward goal & away from control force with money
- Manipulated type of weapon and the ROE
- Approach / Keep away
 - (“Deny access into/out of an area to individuals” JNLE/CBA)
- Recorded spatial data
- Video recording



TDME

UNCLASSIFIED – Approved for Public Release
 TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

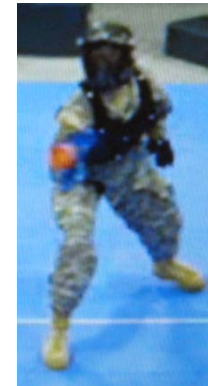
UNCLASSIFIED- Approved for Public Release



- Vicon V8i system
- 24 cameras
- 120 fps
- Optical tracking of retro reflective markers ($\varnothing 14\text{mm}$)
- Marker error $< 10\text{mm}$
- Subjects
 - Unique Helmets
 - XYZ location + 3DOF orientation of head
- Control Force
 - Head & Torso
 - Capability for weapon



Courtesy
Vicon



UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

UNCLASSIFIED- Approved for Public Release



Crowd Studies: Motivation & Behavioral Manipulations



UNCLASSIFIED



UNCLASSIFIED

TECHNOLOGY DRIVEN. **WARFIGHTER FOCUSED.**

TBRL Crowd
Few - Hand -Threat





Individual Metrics



$S_{t,Sa}$	Distance covered in interval
$V_{t,Sa}$	Instantaneous Velocity
$ID_{t,Sa,Sb}$	Interpersonal Distance between any pair of subjects
$CD_{t,c,Sa}$	Distance between control force-subject pairs
$CID_{t,c,c}$	Interpersonal Distance between any pair of control force



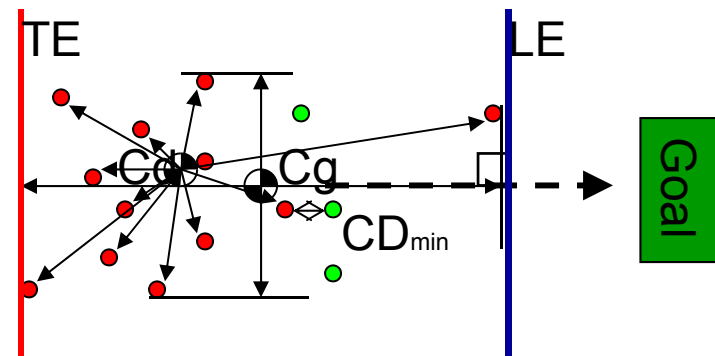
UNCLASSIFIED- Approved for Public Release

12

UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Cg_t	Geometric Center- middle of extrema
Cd_t	Centroid- mean of subject positions
D_t	Dispersion- mean subject radii from centroid
$LE_t TE_t$	Leading/Trailing edge- max/min along the approach axis
ρ_t	Density- $\rho_t = N / \pi D_t^2$
CD_{min_t}	Minimum distance between any subject-control force pair
$\sigma O_t \sigma V_t$	Deviation of Orientation/Velocity- StDev of all subjects head orientation or velocity
Vc_t	Bulk velocity of crowd- rate of change of centroid

Defined time periods based on events dependent on the construct or scenario used.



UNCLASSIFIED – Approved for Public Release
 TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

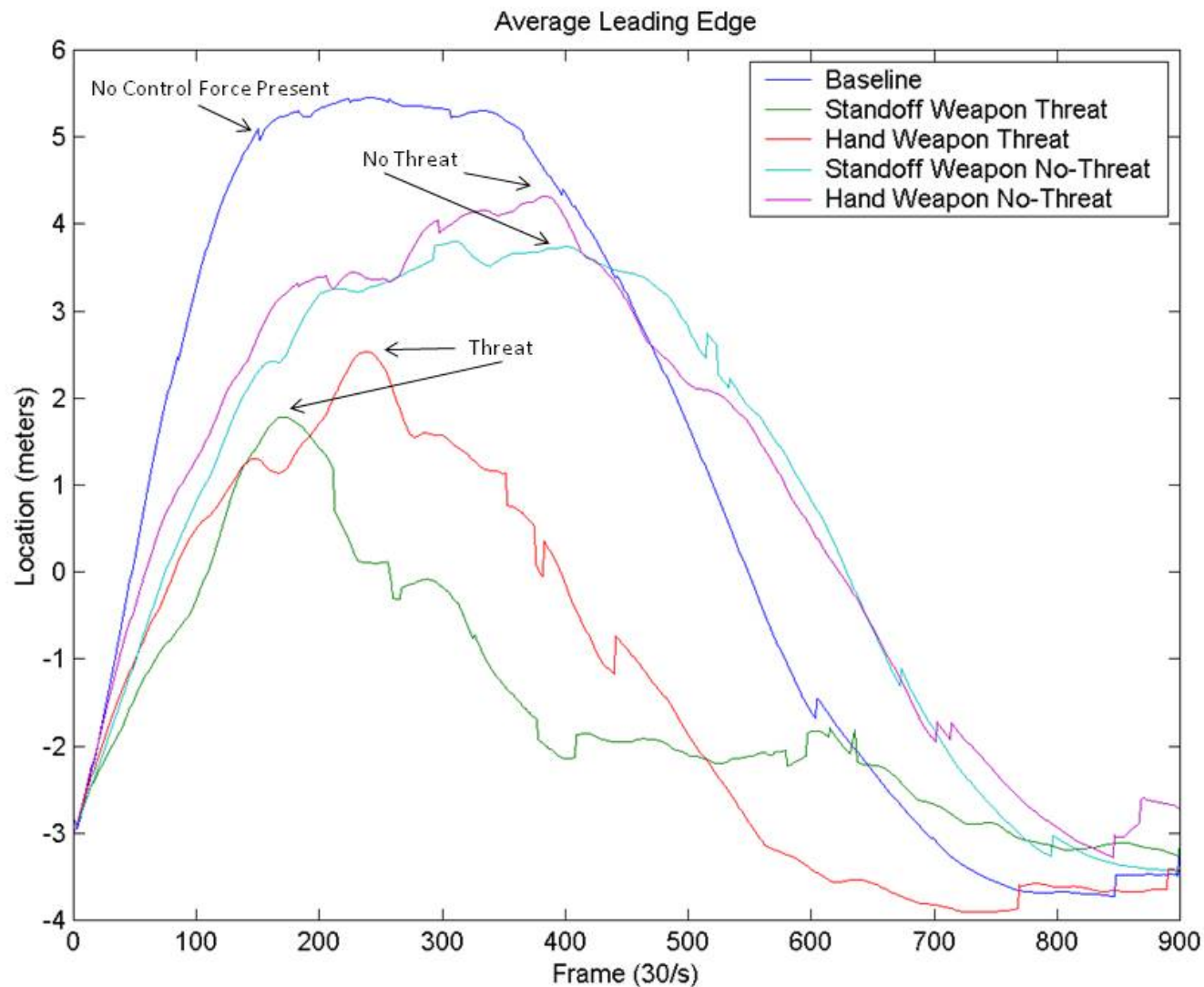
UNCLASSIFIED- Approved for Public Release 13



Metrics for Weapon Performance



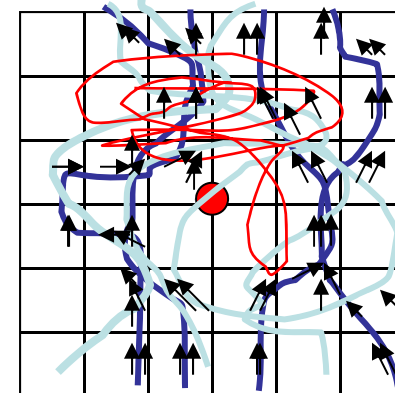
UNCLASSIFIED



UNCLASSIFIED

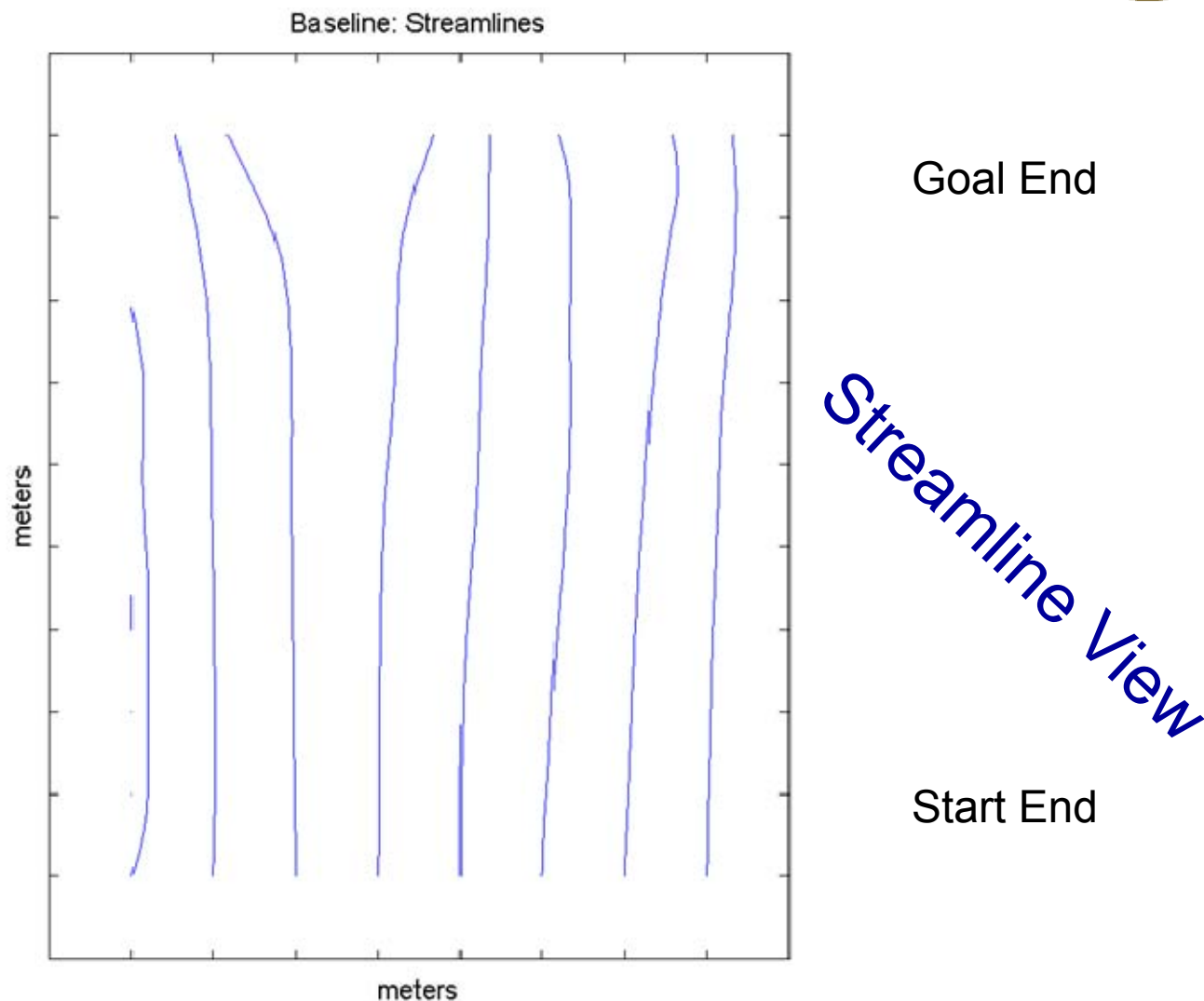
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

- Each subjects path of movement considered separately.
- Coordinate conversion so Control Force is origin.
- Subject locations grouped into cells.
- Resulting vector for a cell is the average vector from all data in that cell.
- Stream lines built from Vector Field.





Baseline Vector Field



UNCLASSIFIED- Approved for Public Release

UNCLASSIFIED- Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

16

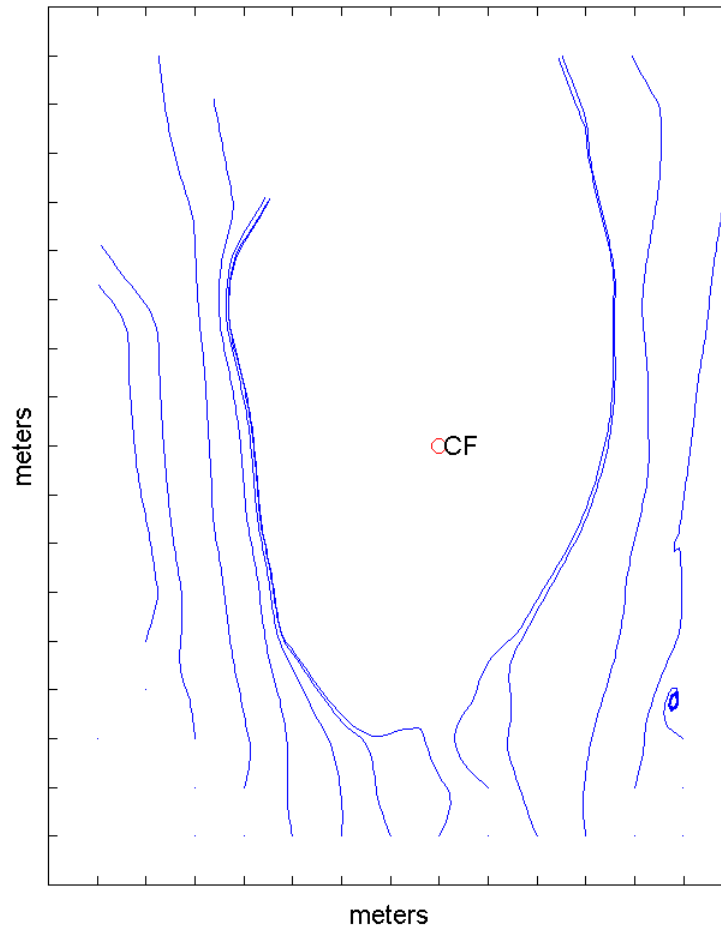


Crowd Metrics for Effectiveness

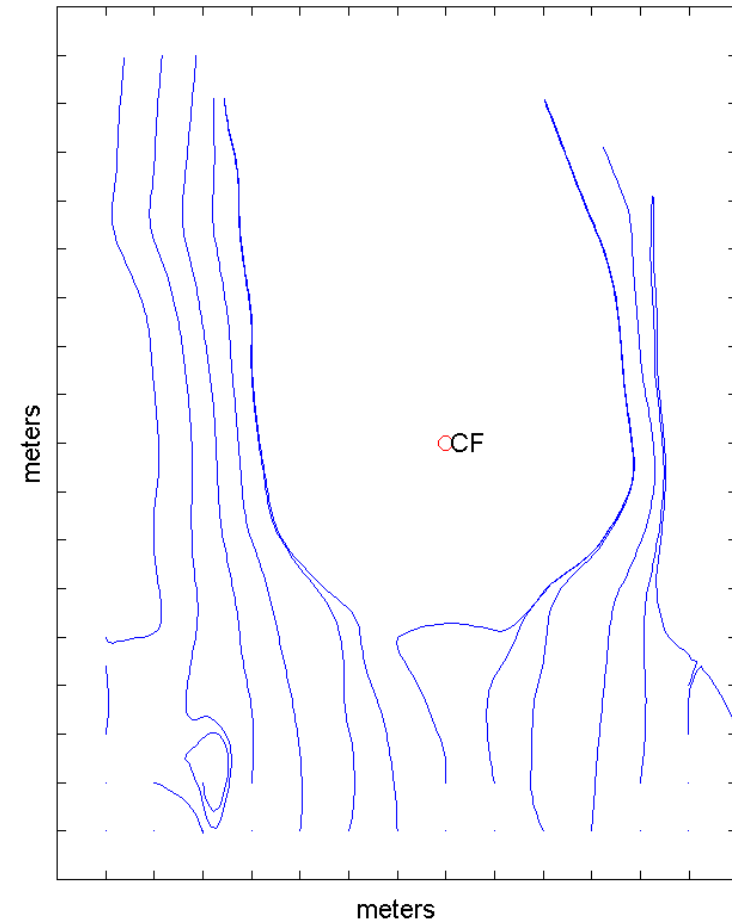


UNCLASSIFIED

Standoff Weapon Threat: Streamlines



Hand Weapon Threat: Streamlines



UNCLASSIFIED

UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Importance of Social Factors



- Response to non-lethal weapons fire depends on social relationships among crowd members
 - Pre-existing Personal Relationships
 - Ongoing Real Time Social Interactions
 - Formal/Informal Hierarchies
- Therefore need method to assess social factors
- Social Network Analysis



13-Feb-15



UNCLASSIFIED- Approved for Public Release

18

UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Data Measurement



- ▶ Social Bonds
 - ▶ Self-Report
- ▶ Crowd Social Interactions
 - ▶ Observed on Video
- ▶ Leader Nomination
 - ▶ Questionnaire



13-Feb-15



UNCLASSIFIED- Approved for Public Release

19

UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Social Network Analysis



- ▶ 19 x 19 matrix submitted to networking analysis software
- ▶ ORA Version 1.9.5.4.3, Dr. Kathleen M. Carley, Center for Computational Analysis of Social and Organizational Systems (CASOS), Institute for Software Research International (ISRI) School of Computer Science (SCS) Carnegie Mellon University
- ▶ Visualization for insight
- ▶ Numerical Sociometrics outputted for formal analyses: density, isolates, linkages among nodes



13-Feb-15



UNCLASSIFIED- Approved for Public Release

20

UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Social Bonds



Do you know anyone else who is participating in the study today?

Yes

No

If yes, please indicate who you know based on the subject number assigned to them (on their tee shirt or folder). Please circle their numbers below:

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20



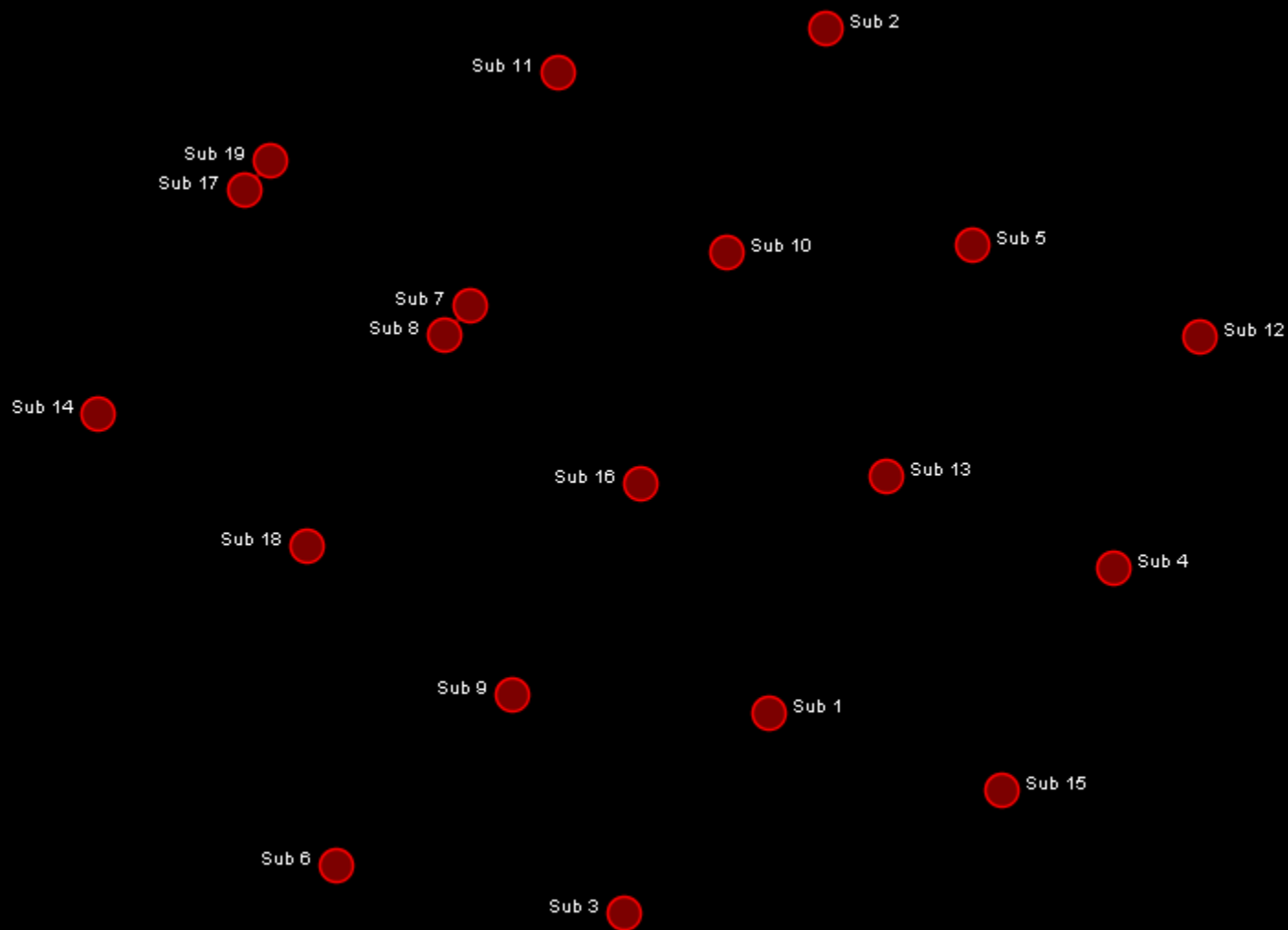
13-Feb-15



UNCLASSIFIED- Approved for Public Release

21

UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Pre-existing Social Bonds



Social Interactions



- Videotapes coded for pair-wise social interaction among crowd members:
 - Verbal communication, physical contact, gestures, non-verbal auditory signaling
 - Scored three 2-minute epochs before/during crowd-control force interaction
 - Inter-rater reliability .94



13-Feb-15

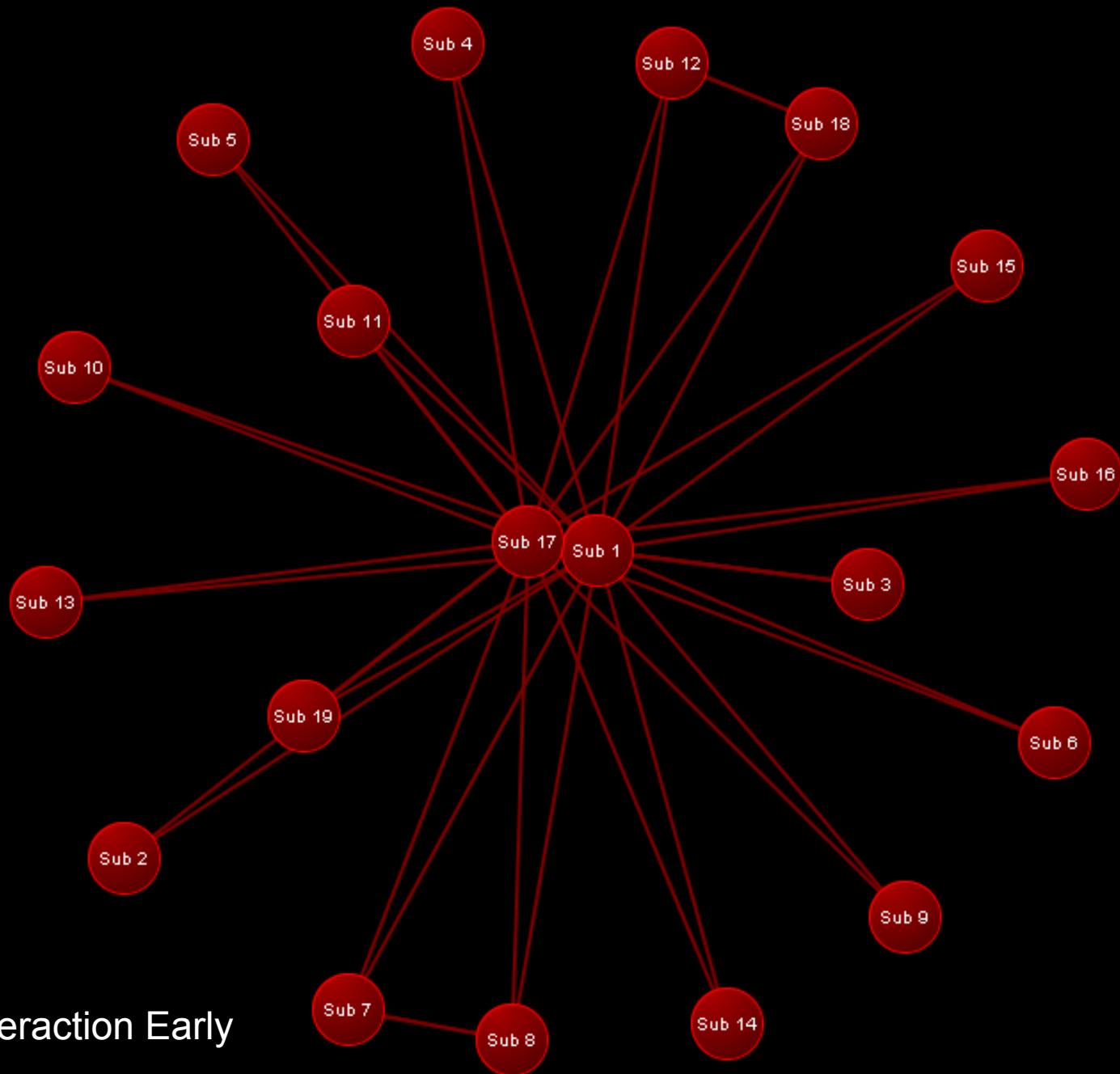


UNCLASSIFIED- Approved for Public Release

23

UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

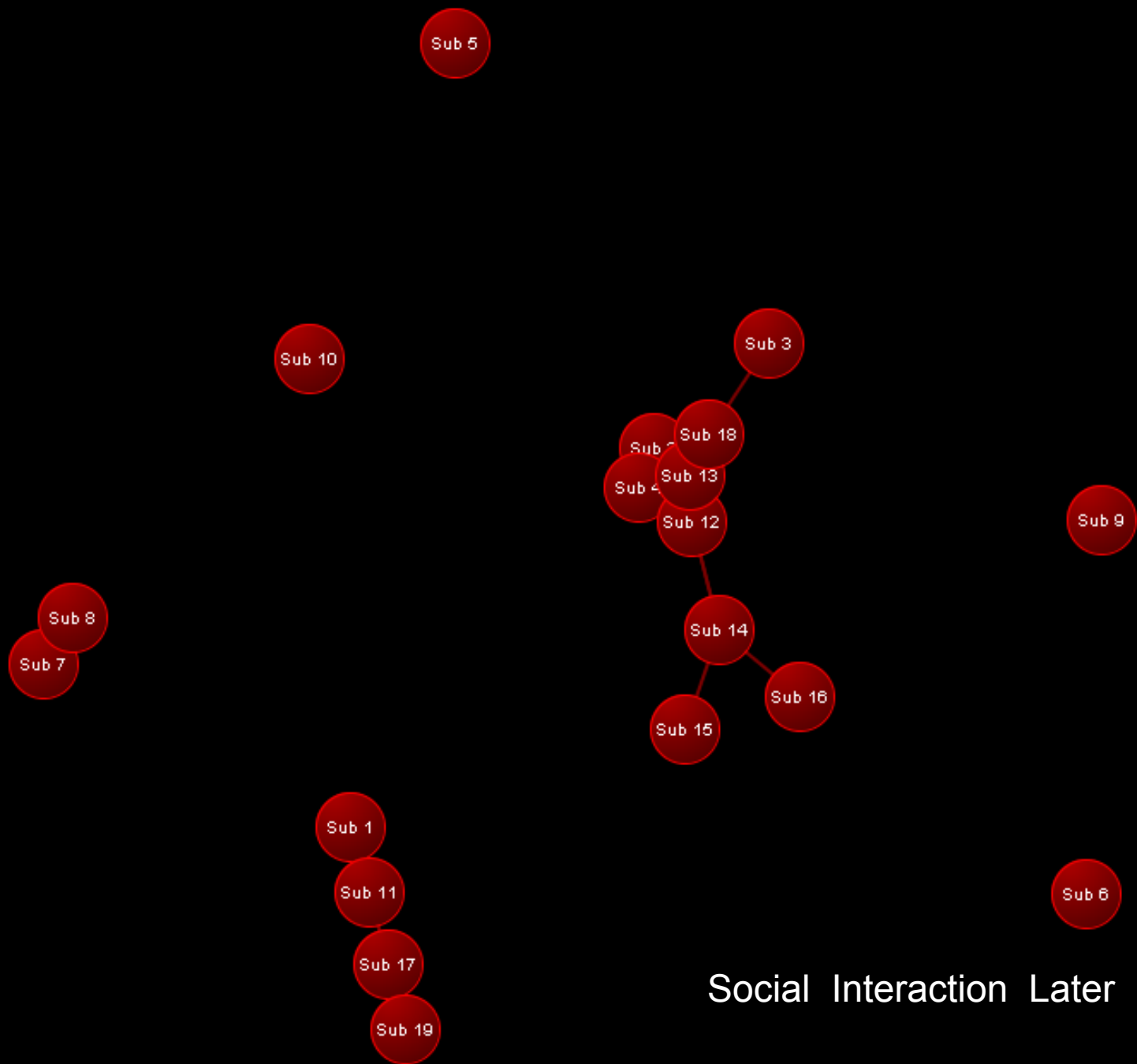
	Sub 1	Sub 2	Sub 3	Sub 4	Sub 5	Sub 6	Sub 7	Sub
Sub 1	0	0	0	0	0	1	0	
Sub 2	0	0	0	0	0	0	0	
Sub 3	0	0	0	0	0	0	0	
Sub 4	0	0	0	0	0	0	0	
Sub 5	0	0	0	0	0	0	0	
Sub 6	1	0	0	0	0	0	0	
Sub 7	0	0	0	0	0	0	0	
Sub 8	0	0	0	0	0	0	1	
Sub 9	0	1	1	0	0	0	0	
Sub 10	0	0	0	0	0	0	0	
Sub 11	0	0	0	0	0	0	1	
Sub 12	0	0	0	0	0	0	0	
Sub 13	0	0	0	0	0	0	0	
Sub 14	0	0	0	0	0	0	0	
Sub 15	0	0	0	0	0	0	0	
Sub 16	0	0	0	0	0	0	0	
Sub 17	0	0	0	0	0	0	0	
Sub 18	0	0	0	0	0	0	0	
Sub 19	0	0	0	0	0	0	0	



Social Interaction Early



Social Interaction Middle





Leader Nominations



Was there a person (or people) in your group that you considered to be a leader (or leaders)?

Yes No

If yes, please indicate all the people that you thought were leaders.

Please circle their numbers below:

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20



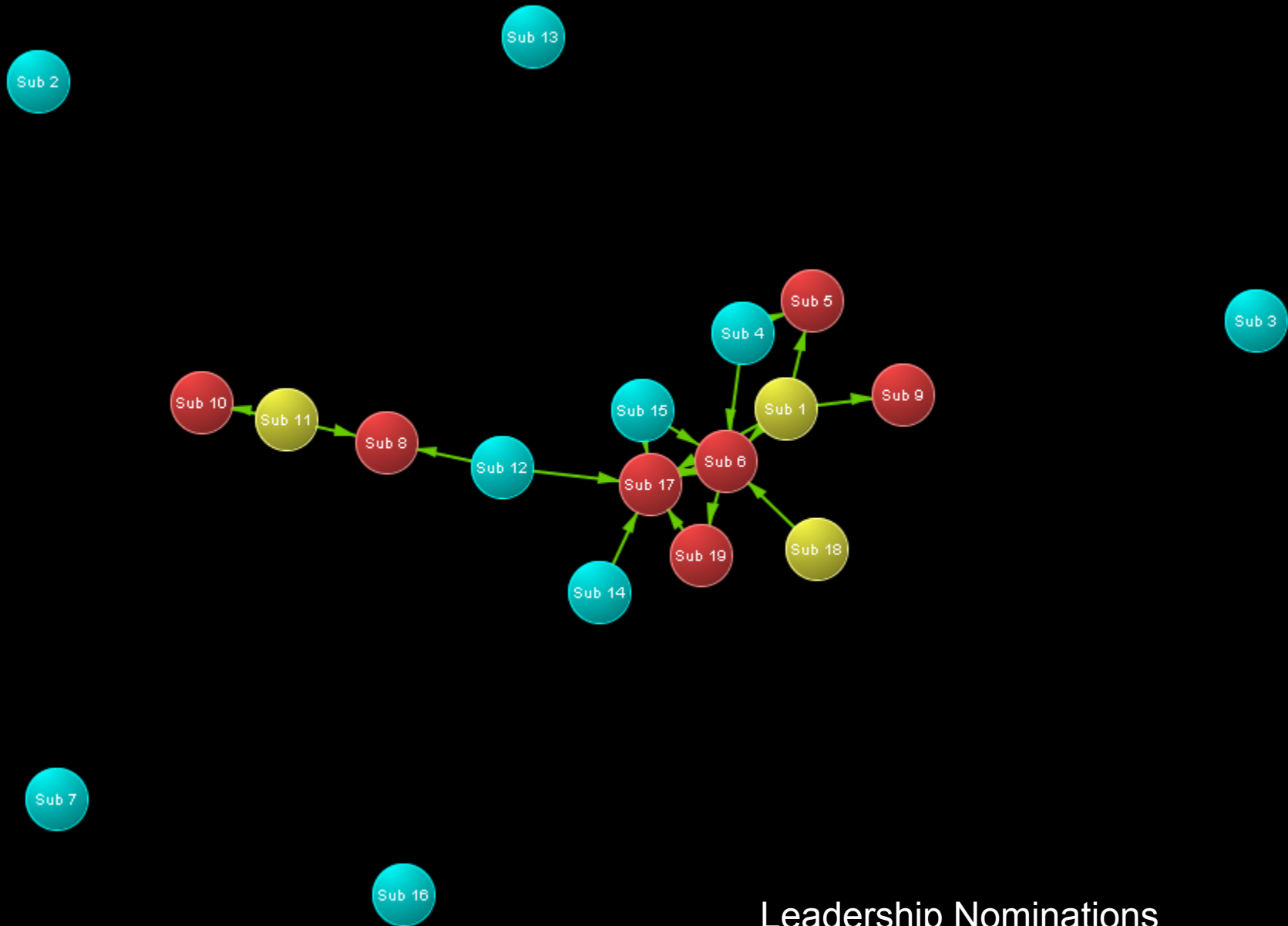
13-Feb-15



UNCLASSIFIED- Approved for Public Release

28

UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Leadership Nominations





Numerical Sociometrics



	Social Bonds	Early Interactions	Late Interactions	Leadership
Node Count	19	19	19	19
Density	0.0117	0.1257	0.0936	0.0526
Fragmentation	0.9883	0	0.7485	0.4678
Isolate Count	15	0	4	5
Link Count	4	43	32	18
Centralization	0.049	0.5114	0.2059	0.1585



13-Feb-15



UNCLASSIFIED- Approved for Public Release

31

UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Lewinian Field Theory



Conceptualization of Behavior

- $B=f(P,E)$ Behavior is a function of the Person and the Environment
- Behavior can be expressed in mathematical terms
 - Easily imported into modeling and simulation exercises
- The challenge to researchers is to identify the totality of relevant factors and the elimination of extraneous factors



UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Factors in Crowd Response to Non-lethal Weapons and Systems



- **Weapon Variables:**

- Visibility (can you see it)
- Predictability (can you tell where it's going to hit)
- Controllability (can do something to avoid being hit)
- Ability ("Effects" damage to persons)

- **Environmental Factors:**

- Cover
- Escape Routes
- Barriers

- **Individual Psychological Factors:**

- Motivation toward forbidden goal
- Competing motivations

- **Crowd Social Factors:**

- Organizational Hierarchy
- Interpersonal Attraction
- Alignment of motivations (do they all want the same thing)
- Communication Ability



UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Algorithms for M & S



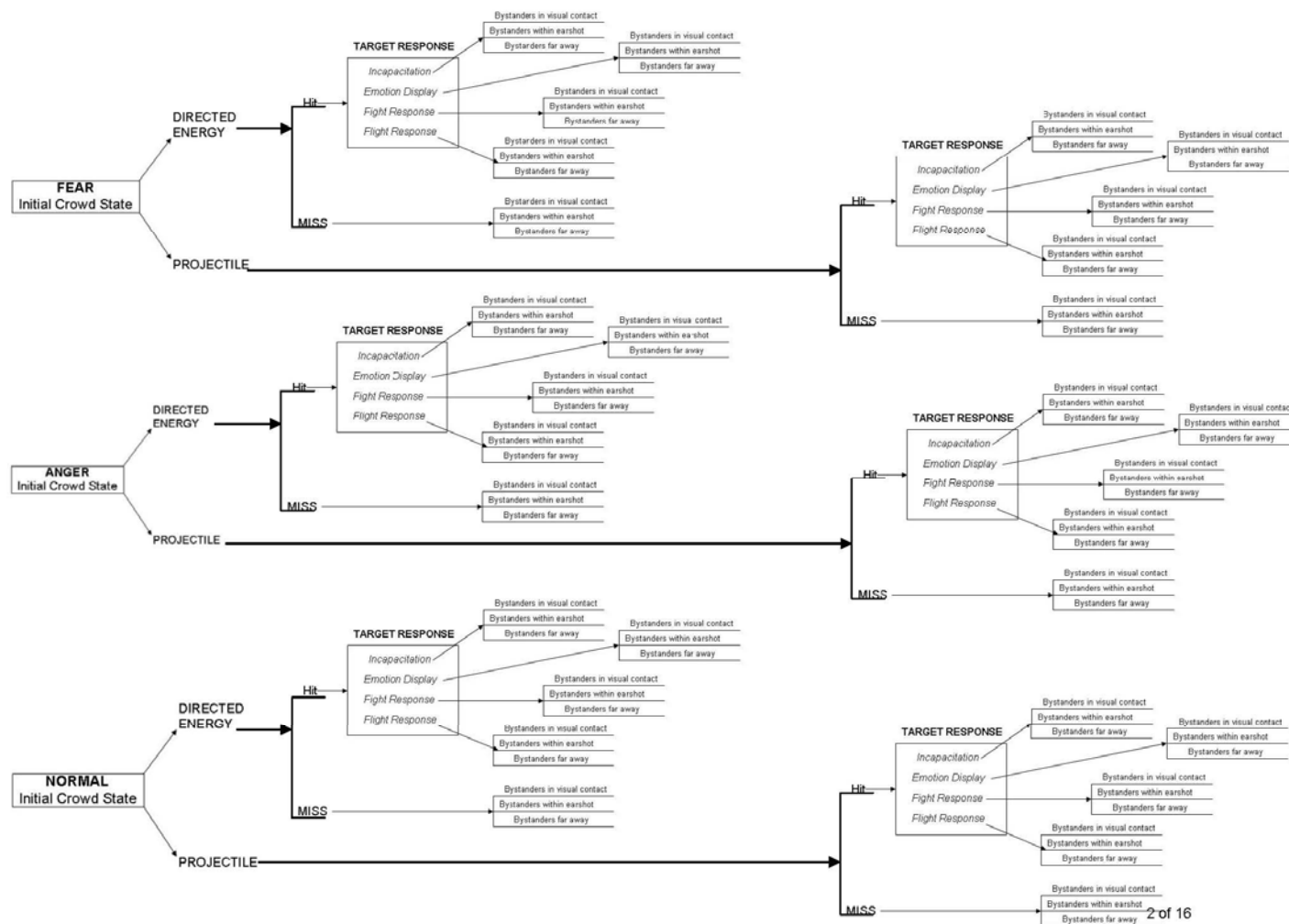
- $y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \dots + \beta_{12} x_1 x_2 \dots + \epsilon$
- “Behavior is a weighted function of variable x_1, x_2, x_3 their interactions, and error.”
- y is Output
- x are Inputs (Weapons, Environment, Individual, and Crowd Social Factors)



UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



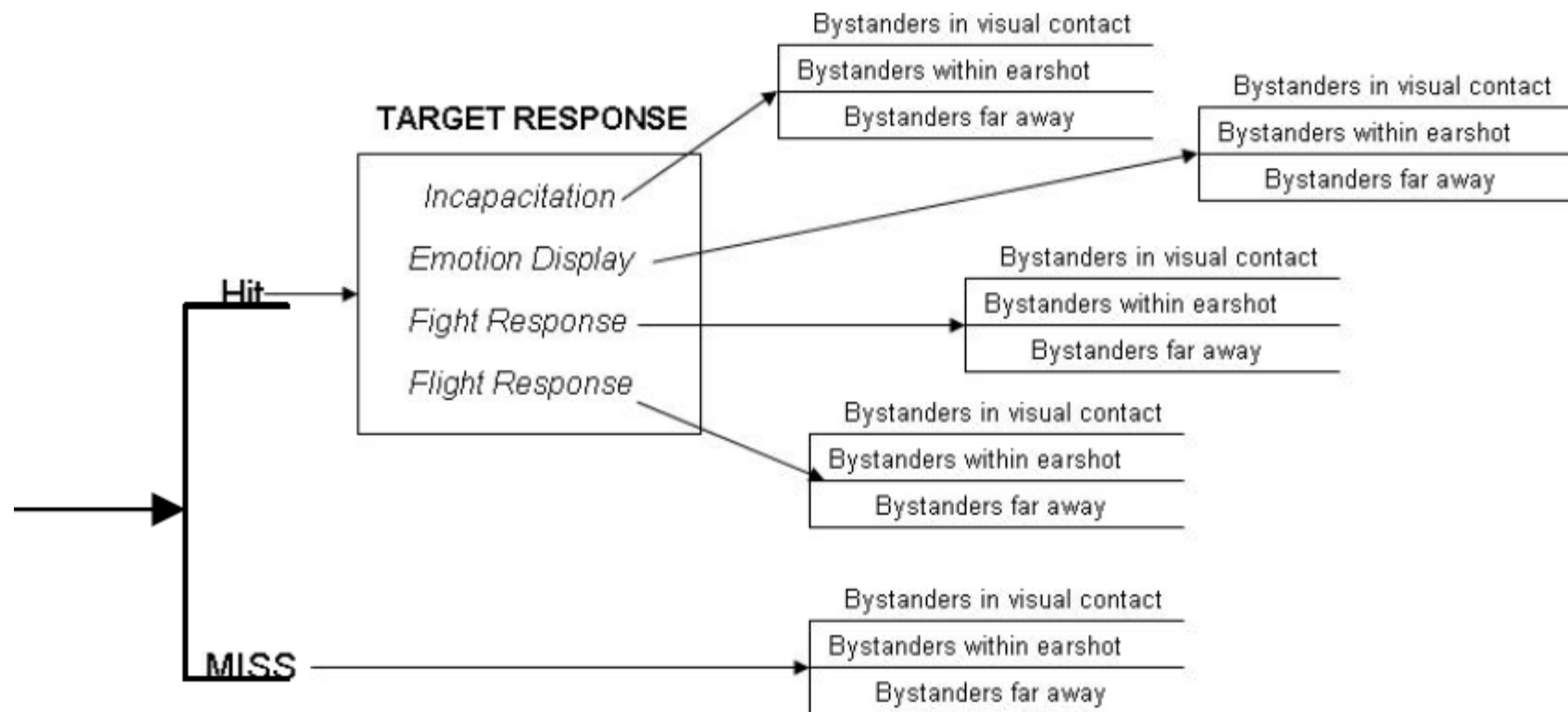
Crowd Model



UNCLASSIFIED – Approved for Public Release
 TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Model Detail



UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Validation



- Need to make/use against real world observations
- Challenge is to measure
 - Challenge is to find recorded measures
 - Beware of circularity
 - Can't use same data that you've built the model for validation
 - Requires control over factors



UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Modeling Building



UNCLASSIFIED

- Quantitative Crowd Metrics allow algorithms to be made
- Algorithms can be used for to build models
- Output and Predictions of applications can be compared to data recorded in lab
- Visualization alone is helpful



UNCLASSIFIED

UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Using Data to Build Models



UNCLASSIFIED

- Comparison of VICON data with computer simulation with same parameters
- MAICE Station™

Crowd Modeling Application Version 1

Southwest Research Institute

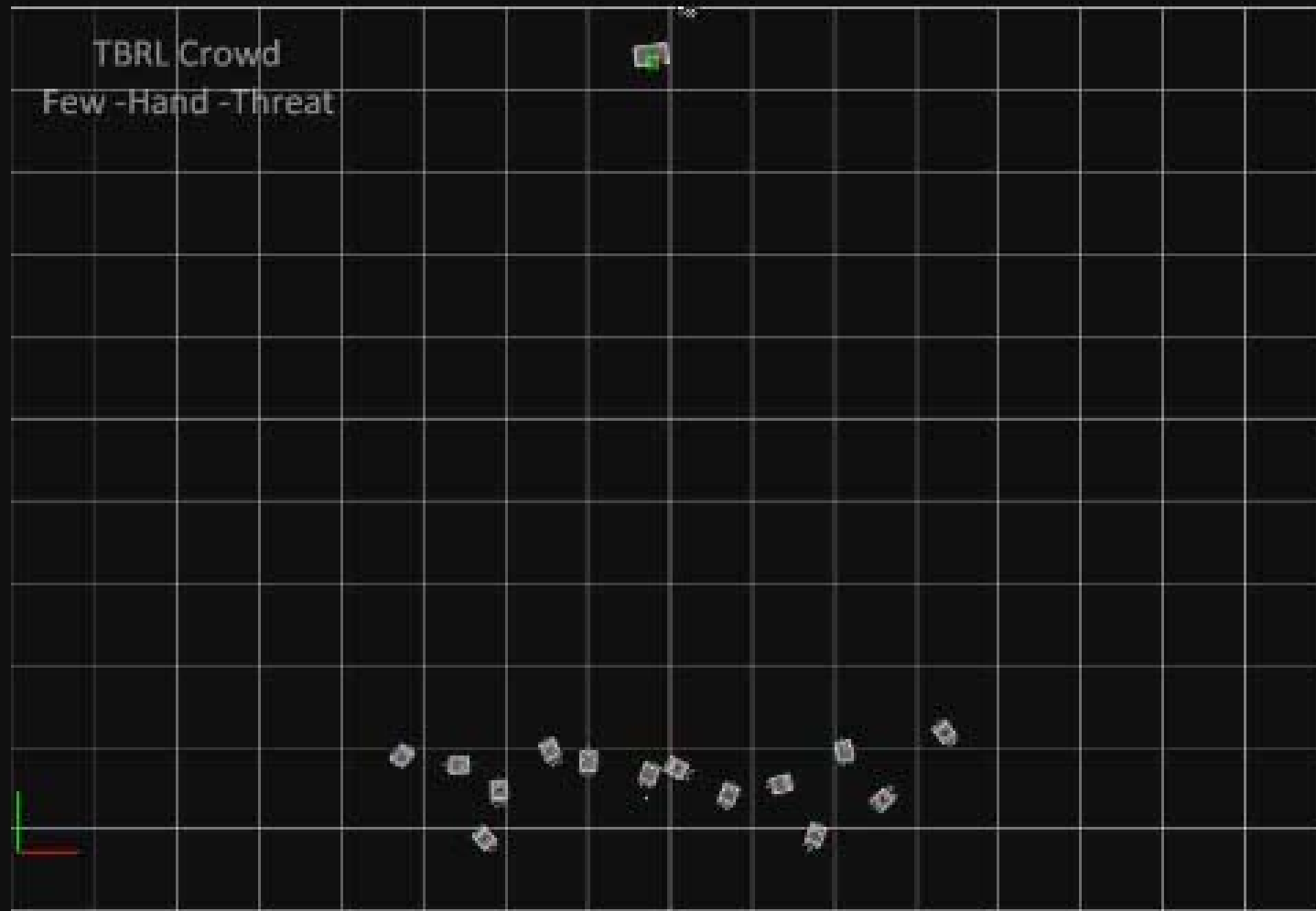
www.tspi.swri.org



UNCLASSIFIED

UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

UNCLASSIFIED



UNCLASSIFIED





Critical Elements for Data Feed into Modeling Efforts



UNCLASSIFIED

- Common Conceptualization of
Crowd Behaviors

Lewinian Field Theory

- Common Metrics
- Common Data Formats
- Common Inputs
- Common Outputs
- Common Statistical Analyses



UNCLASSIFIED

UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Using Data for Model Validation



UNCLASSIFIED

- Build model around a scenario with one level of a parameter using real human data
- Run model with a different level of a parameter and record output metrics and predictions
 - Real human data must exist at this level of the parameter
- Compare output of model to analyses of laboratory data of real humans



UNCLASSIFIED

UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Model Validation: Examples



UNCLASSIFIED

Build Model On

- One Control Force
- Hand-to-hand Combat Weapon
- 10 in crowd

Validate Against

- Three Control Force
- Stand-off Weapon
- 20 in crowd



UNCLASSIFIED

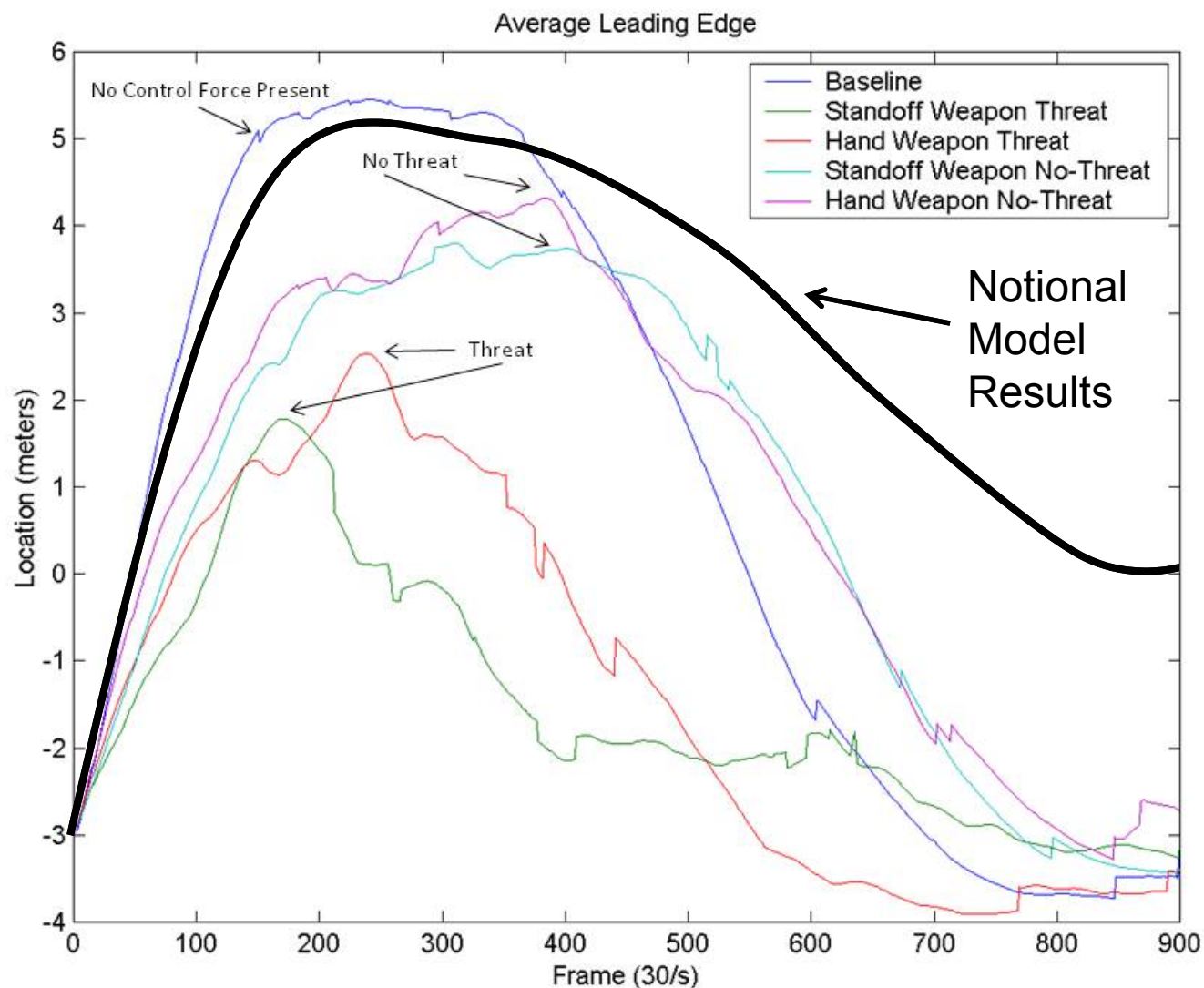
UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Comparison of Data and Output



UNCLASSIFIED



UNCLASSIFIED

UNCLASSIFIED – Approved for Public Release
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.